Effect of Air Gap on CsI Light Yield

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Because of the difficulty in finding reliable glue joints between PIN photodiodes and CsI bars, it is interesting to consider the possibility of eliminating the optical glue or coupling compound entirely, instead relying on an air or vacuum gap between the diode and the crystal. During our initial bonding tests we did several studies of the effect on the scintillation light yield from an air gap. We found that **air gaps of moderate thickness (from negligible to 5 mm) reduced the scintillation light approximately in half, relative to bonds with optical grease or hard epoxy**. The loss in light depended only weakly on the thickness of the gap and on whether the crystal end face was polished or roughened.

The most thorough tests were performed on 16 June 1999 (on a 310 mm bar) and 3-4 February 2000 (on 310 and 370 mm bars). In all cases tests were performed with CsI(Tl) crystals from Crismatec or Amcrys H. The cross section of all crystals was 23 mm by 30 mm. The crystals were wrapped in Tetratek and adhesive aluminized Mylar. In all cases, the crystals were read out with the 1 cm^2 PIN photodiode of the custom Hamamatsu dual photodiode. Signals were amplified by eV Products 5093 preamps and Mechtronics shaping amps. The crystals were illuminated near their centers with a collimated 2.6 MeV beam from ^{228}Th. The collimator aperture was typically about 3 cm. Data from the two crystal faces were logged simultaneously with our custom Homer data acquisition system.

The June 1999 tests were performed on Amcrys crystal U-02-34 with a good Epotek 301 epoxy bond holding one PIN diode in place. On the opposite face we coupled the PIN to the crystal with optical grease. We then removed the greased PIN and cleaned the crystal face with ethanol, then held a clean PIN just off the surface of the crystal. The 2.6 MeV peak appeared in approximately the same ADC bin from the PIN with epoxy bond and the PIN with optical grease, but it appeared at only half the pulse height from the PIN with an air gap.

The February 2000 tests were performed with Amcrys crystal U-02-46 (310 mm in length) and Crismatec crystal #4 (370 mm in length). On one end of each crystal, we mounted a dual PIN with optical grease and held it in place with Kapton tape. On the opposite face, we mounted a dual PIN on a fixture that allowed varying separation between the crystal face and the diode face, from dry contact up to 5 mm in gap.

Thorium spectra are shown in Figure 1 for the Crismatec crystal. From the PIN coupled with optical grease (black spectrum), a shoulder is visible at the 2.6 MeV photopeak, and the first and second escape peaks are visible. With the PIN in dry contact with the crystal face (cyan spectrum), the 2.6 MeV shoulder appears at about half the amplitude as with optical grease. An air gap of 1.5 mm (magenta) gives light yield essentially equal to dry contact. Finally, an air gap of 5 mm (dark blue) gives ~15% less light still. Data from a run with a 3 mm gap are not plotted but, not surprisingly, they show light yield just slightly less than from the 1.5 mm gap.

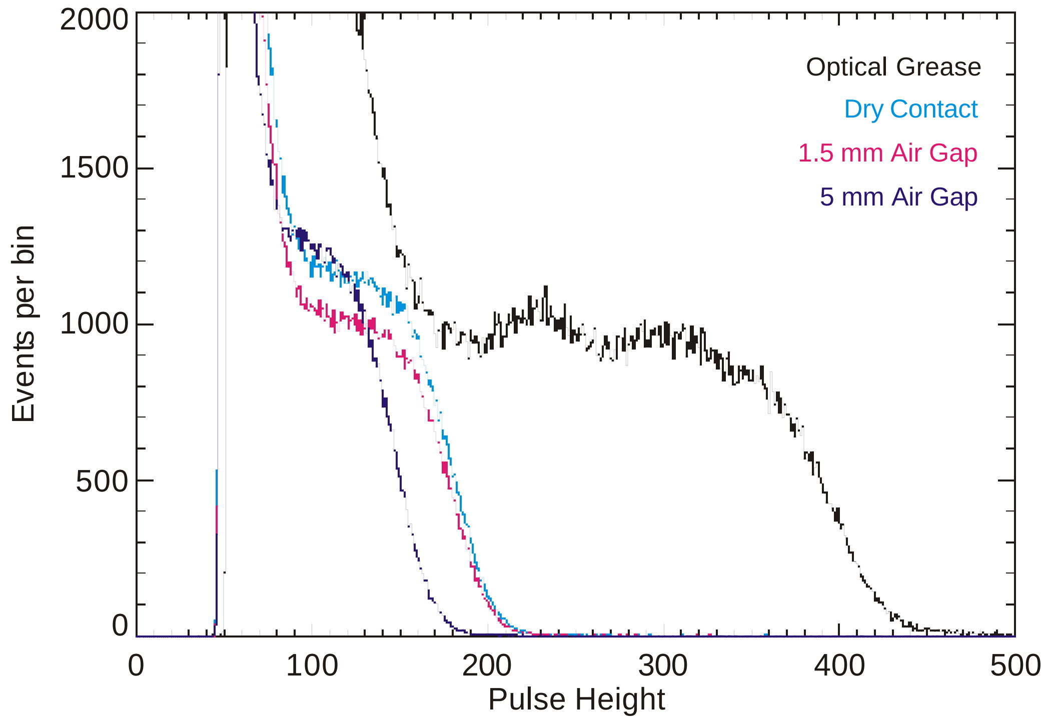

Figure 1: Thorium spectra from 370 mm Crismatec crystal in 1 cm^2 PIN photodiode coupled with optical grease (black), in dry contact (light blue), or with an air gap of 1.5 mm (magenta) or 5 mm (dark blue).

The end faces of the Crismatec and Amcrys crystals were polished at the factory. We tested whether roughening the end surface could increase the light yield. We first sanded one end face of Amcrys crystal U-02-46 with 400-grit sandpaper and removed the CsI dust with a gentle ethanol wipe. We accumulated a thorium spectrum before and after the roughening. Then we further roughened the end face with 240-grit sandpaper and again removed the CsI dust. Figure 2 shows thorium spectra from the polished end (black) and the end after the 240-grit sanding (cyan) with the PIN in dry contact with the crystal face. Roughening the end face decreased the light yield by ~5–10 %.

We conclude that air gaps from miniscule up to a few millimeters reduce the light collection efficiency by approximately half, and that roughening the end surface of the crystal does not improve the light yield.

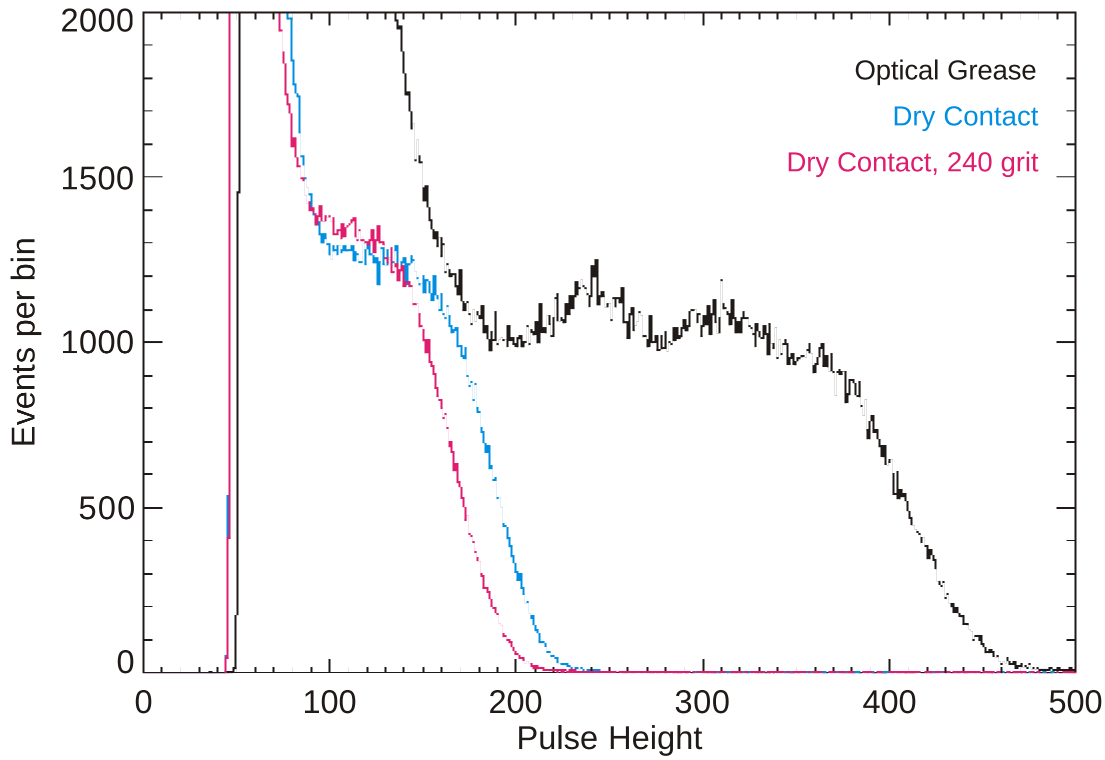

Figure 2: Thorium spectra from 310 mm Amcrys crystal into 1 cm^2 PIN photodiode coupled with optical grease (black), in dry contact against a factory-polished face (light blue), and in dry contact against a face roughened with 240-grit sandpaper (magenta).